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(54) Method and apparatus for reducing the peak-to-average power in multi-carrier RF communication systems

Verfahren und Vorrichtung zur Reduzierung der Spitzenleistung zur mittleren Leistung in einem Multiträger HF-Kommunikationssystem

Procédé et dispositif pour la réduction du rapport puissance de crête et puissance moyenne dans des systèmes de communication radiofréquences à portées multiples

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Description

This invention relates to power amplifier systems, and to methods of increasing an average power handling capacity of a single power amplifier in a power amplifier system.

In wireless telephone communication systems the power signals of many channels are combined into a composite signal. This composite signal is split into many parallel paths and coupled to individual radio transmitters in each parallel path. The output radio transmission signals of the plurality of radio transmitters are combined and amplified in a single power amplifier. Individual signal peaks in each of the parallel paths may coincide and cause a composite peak power to occur at the single power amplifier that greatly exceeds its power handling capacity.

The various radio channels are distributed in frequency with respect to each other in that each operates within a different frequency band. Each channel is FM modulated and hence has a signal of substantially constant amplitude. The peak occurrences of the combined signal is a highly complicated function of the individual carrier frequencies, modulation methods, signal contents and noise. Since the simultaneous occurrence of individual signal peaks can not easily be avoided, a multi-channel signal is subject to power maximums where the peak power significantly exceeds the average power of the envelope due to constructive addition of the individual signals.

U.S. patent 4,064,464 discloses an amplifier system, including a power splitter for dividing an input signal into a plurality of channels and feeding each channel into a plurality of power amplifiers connected in parallel. The several output of the parallel connected power amplifiers are combined into a single output by a subsequent power combiner connected to the paralleled outputs of the power amplifiers. The input to one of the paralleled amplifiers includes a voltage controlled phase shifter that is responsive to a deviation of the power output of the power combiner from a reference value. This feedback arrangement maintains the power output at a regulated value. This is however, an amplification technique having individual amplifiers in each of a plurality of channels rather than amplifying a combined signal of a plurality of channels of radio transmission signals in a single amplifier.

According to one aspect of this invention there is provided a power amplifier system as claimed in claim 1.

According to another aspect of this invention there is provided a method as claimed in claim 2.

Brief Description of the Drawing

In the Drawing:

FIG. 1 is a block schematic of an amplifier system control arrangement to limit the peak to average

power ratio;

FIG. 2 is a block schematic of an another amplifier system control arrangement to limit the peak to average power ratio;

FIG. 3 is a block schematic of a stored program controller used in the amplifier control systems of FIGS. 1 and 2;

FIGS. 4 and 5 are graphs of waveforms of envelope power processed by the amplifier system; and

FIG. 6 is a flow process diagram of the method of reducing the peak to average power ratio.

Detailed Description

15 An exemplary system for reducing the peak to average power in an amplifier processing a plurality of different signal channels spaced apart in frequency from one another; each channel having a different carrier frequency is shown in the FIG. 1. The apparatus shown is

20 included in a cellular base station in which the phase locked radios each handle a different channel in the channel set assigned to the cell served by the cellular base station.

A plurality of phase locked radio transceivers, 101,

25 102, 103 and 104, are connected to receive audio and data designated as information signals. These signals are FM modulated and transmitted at different carrier frequencies for each of the phase locked transceivers. The FM signals (radio frequency output signals) are in-

30 dividually transmitted, via leads 111, 112, 113 and 114, to a combiner circuit 106 that combines all the modulated carrier signals into a composite modulated signal including all the information supplied to the radios 101-104. This composite signal is applied to the preamplifier 107 and subsequently to a linear amplifier 109 which amplifies the composite signal to a radio trans-

35 mission level. The linear amplifier output is connected to an antenna 110 for transmission to the cell area.

The frequencies of the carrier signals in each of the

40 radios are synchronized to a reference frequency supplied from a reference signal derived from a reference frequency generator 121. The output of the reference frequency generator 121 is applied to a signal splitter apparatus 122 which applies the reference frequency

45 signal onto the four leads 123, 124, 125 and 126. These four leads are coupled to the voltage controlled phase shifters 131, 132, 133 and 134, whose operation is discussed subsequently. The output of the phase shifters is connected via leads 143, 144, 145 and 146 to refer-

50 ence signal inputs of the phase locked radios 101-104.

In this illustrative arrangement the carriers of the transceivers are equally spaced apart in frequency. In this instance, the peak to average reduction is most advantageous. Each radio is locked to the same reference frequency supplied to the leads 123-146. Due to thermal effects in the phase locked loops, the carrier frequencies drift with respect to each other and, as shown in FIG. 4, the peaks of several carriers may coincide in time pro-

ducing a high peak envelope power in the linear amplifier. In general, the envelope of the combined signals are periodic at the rate of $\frac{1}{T}$ is the frequency spacing between carriers. These envelope peaks may exist for extended periods of time, which is associated with the thermal draft of the phase locked transceivers.

The power input to the linear amplifier 109 is sensed by the coupling device 151 which is connected to an average power detector 152 and a peak power detector 153. The values for average power and peak power are applied to a controller 161. The Controller, which may be implemented in either digital or analog form, continuously monitors the peak power to average power ratio of the signal processed by the linear amplifier 109. Controller 161 includes circuitry to evaluate this ratio and uses the information to apply control voltages, via leads 171, 172, 173 and 174, to the voltage controlled phase shifters 131-134. In the illustrative embodiment this control circuit may comprise stored program control, logic arrays or analog circuitry.

In the arrangement of FIG. 1, a 1 to 3 degree phase shift of the reference frequency inputs corresponds to a 60 to 180 degree phase shift at the RF outputs since the ratio of the radio frequency to the reference frequency is equal to 60. The phase shift for each individual carrier is applied to the corresponding reference signal input to which the radio carrier is synchronized. In the illustrative embodiment this reference frequency is in the 15 MHz range.

A typical stored program controller suitable for use as the controller is shown in the FIG. 3. The controller monitors the average and peak envelope powers of the input signal to the Linear amplifier. The average power herein is understood to be the thermal equivalent power, averaged over a time period longer than the fluctuations of the envelope power, perhaps 100 mS. The peak power is that power detected by a classical video diode peak detector, which stores the peak value in a capacitor which decays at a rate somewhat slower than the frequency of occurrence of the peaks.

By measuring both the peak and average powers, the controller of FIG. 3 can compute the peak to average ratio of the signal and optimize for a minimum ratio. The hardware implementation, as shown in the FIG. 3, includes two analog to digital converters, 301 and 302 which receive input from a peak detector (153 in FIG. 1) and an average power detector (152 in FIG. 1) respectively, and apply a digitized version of the peak and average power to a microprocessor. The microprocessor includes associated RAM (304) and ROM (305) memory capacity, which provide memory storage and stored instructions for controlling the processing of the sensed power signals and generating the output control signals to control the phase shifting circuitry (131 - 134 in FIG. 1). The microprocessor 303 feeds digital phase shift control signals to one or more of a set of digital to analog converters 331 - 334 which in turn supply analog control signals to control the phase shift circuits 131-134 shown

in FIG. 1. While the illustrated controller uses a microprocessor and digital signals it is to be understood that a completely analog controller can be used, with sample and holds and comparators and op amps.

- 5 Optimization of the peak to average power ratio is done with a successive trial and error procedure, since the correlation between phase of a given radio and the peak to average ratio of the combined radio signal is very complex, and because the absolute phase of a given radio is not easily controllable. The controller adjusts one or more of the phase shifters at a time, then monitors the peak to average ratio. If there is an improvement (decrease) in the peak level, the controller continues phase adjustment in the same direction. When a minimum peak to average ratio is achieved, as evidenced by a dip in the peak power envelope, the controller stops adjustment of that phase shifter and goes on to the next phase shifter in sequence. Each phase shifter is set in sequence, and then the controller repeats the cycle. In some applications it may be sufficient to just monitor the peak value of the power envelope.
- 10 The process of changing the phase of a radio, according to the instructions of the stored program of the controller, for a particular one of the radios N, is shown in flow chart form in the FIG. 6. The flow starts in the terminal 601 and the instructions of block 603 cause the peak envelope and average power to be measured and the peak envelope to average power ratio to be calculated. The instructions of decision block 605 determine if the absolute difference between the most recent peak/average ratio measurement and the previous peak/average ratio measurement is greater than some minimum quantum phase value. This quantum value is an absolute value of phase change below which the phase of the current radio is considered to be optimum.
- 15 If the absolute difference in decision block is greater than the minimum quantum phase value the flow proceeds to decision block 609 whose instructions determine the most recent peak/average ratio is greater than the previous peak/average value. If it is not the phase of radio N is changed by some quantum value. The last computed peak/average ratio is made the most recent value in the block 615 and the flow process returns to the block 603.
- 20 If the response to the evaluation of decision block 605 is a no answer the flow proceeds to the block 607 which changes the N designation of the radio being adjusted to the next radio. The phase of this radio is changed as per the instructions of block 613.
- 25 In response to an affirmative response to decision block 609 the flow proceeds to block 611, whose instructions change the direction of the phase shift implemented. The radio phase is shifted in accord with the instructions of block 615.
- 30 The wave form, of FIG. 4 shows the occurrences of high peaks in the multicarrier signal envelope of the type that limit the peak power handling capacity of a linear amplifier system. The peaks 401 are significantly higher
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than the average power level 402.

The improvement achieved by the method and apparatus to reduce these peaks is shown in FIG. 5 where the peaks 501 relative to the average power level 502 is much reduced compared to the FIG. 4.

An alternative arrangement for preventing high to peak-to-average power ratios from occurring is shown in the FIG. 2. The system components are substantially identical to those described with reference to the FIG. 1 system, but their relative positioning is altered. The chief alteration is the positioning of the voltage controlled phase shifters 231-234 to phase shift the carrier at the outputs of the transceivers 201-204. This repositioning requires phase shifts in the order of 60 to 180 degrees to be effective. Otherwise the operation is substantially similar to the operation of the phase shift system of FIG. 1. The controller used here is identical to the controller of FIG. 3 except for the phase shift increment used.

Claims

1. A power amplifier system for a radio transmission communication system; including :

a power splitter (122) for dividing an input composite signal into a plurality of parallel channels (123-126);
a power combiner (106) connected to combine the signals on the parallel channels into a single output channel (107);

CHARACTERIZED BY:

each of the parallel channels including a radio transmitter (101-104);
an amplifier for amplifying the signal on the single output channel (109);
means for monitoring a peak power level (153) of the signal on the single output channel;
means for monitoring an average power level (152) of the signal on the single output channel;
means for developing a ratio of peak power to average power (161) connected to receive inputs from the means for monitoring a peak power and means for monitoring an average power;
means for altering phases (131-134) of the signals of the radio transmitters in response to the means for developing when the ratio exceeds a specified value.

2. Method of increasing an average power handling capacity of the single power amplifier, in a power amplifier system processing a composite radio carrier signal in a plurality of parallel channels each including a radio transmitter with the parallel channels fed into a single channel including a single power amplifier, CHARACTERIZED BY the steps of:

monitoring a peak power level of the single channel handled by the single power amplifier and determining if it exceeds a power threshold;

altering a phase of one of the radio carrier signal in at least one of the parallel channels if the peak power exceeds the threshold;
again determining if the peak power exceeds the threshold;
altering a phase of the radio carrier signal in another one of the parallel channels; and
ceasing alteration of phases of the radio carrier signals when the peak power does not attain the threshold.

Patentansprüche

1. Leistungsverstärkersystem für ein Funkübertragungskommunikationssystem mit folgenden:

einem Leistungsteiler (122) zum Aufteilen eines Eingangssignalgemisches auf eine Mehrzahl von parallelen Kanälen (123-126);
einem zum Kombinieren der Signale auf den parallelen Kanälen in einen einzigen Ausgangskanal (107) geschalteten Leistungskombinierer (106);

gekennzeichnet durch folgendes:

daß jeder der parallelen Kanäle einen Funksender (101-104) enthält;
einen Verstärker zum Verstärken des Signals auf dem einzelnen Ausgangskanal (109);
Mittel zum Überwachen eines Spitzenleistungspegels (153) des Signals auf dem einzelnen Ausgangskanal;
Mittel zum Überwachen eines Durchschnittsleistungspegels (152) des Signals auf dem einzelnen Ausgangskanal; Mittel zum Entwickeln eines Verhältnisses von Spitzenleistung zur Durchschnittsleistung (161), die zum Empfangen von Eingaben von den Mitteln zum Überwachen einer Spitzenleistung und Mitteln zum Überwachen einer Durchschnittsleistung geschaltet sind;
Mittel zum Ändern der Phasen (131-134) der Signale der Funksender als Reaktion auf die Mittel zum Entwickeln, wenn das Verhältnis einen angegebenen Wert überschreitet.

2. Verfahren zum Steigern einer Durchschnittsbelastbarkeit des einzelnen Leistungsverstärkers in einem Leistungsverstärkersystem, das ein Funkträgersignalgemisch in einer Mehrzahl von parallelen Kanälen verarbeitet, die jeweils einen Funksender enthalten und wobei die parallelen Kanäle in einen

einzelnen Kanal mit einem einzelnen Leistungsverstärker eingespeist werden, gekennzeichnet durch folgende Schritte:

- Überwachen eines Spitzenleistungspegels des vom einzelnen Leistungsverstärker bearbeiteten einzelnen Kanals und Bestimmen, ob dieser Pegel einen Leistungsschwellwert überschreitet; 5
- Ändern einer Phase eines der Funkträgersignale in mindestens einem der parallelen Kanäle, wenn die Spitzenleistung den Schwellwert überschreitet; 10
- erneut Bestimmen, ob die Spitzenleistung den Schwellwert überschreitet; 15
- Ändern einer Phase des Funkträgersignals in einem anderen der parallelen Kanäle; und Beenden der Änderung von Phasen der Funkträgersignale, wenn die Spitzenleistung nicht den Schwellwert erreicht. 20

Revendications

1. Système d'amplificateur de puissance pour un système de communication de transmission radio; comportant:

- un diviseur de puissance (122) pour diviser un signal composé d'entrée en une pluralité de voies parallèles (123 à 126); 30
- un combinateur de puissance (106) connecté pour combiner les signaux sur les voies parallèles en une voie de sortie unique (107);

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CARACTERISE PAR:

- chacune des voies parallèles comportant un émetteur radio (101 à 104);
- un amplificateur pour amplifier le signal sur la voie de sortie unique (109); 40
- un moyen pour contrôler un niveau de puissance de crête (153) du signal sur la voie de sortie unique;
- un moyen pour contrôler un niveau de puissance moyen (152) du signal sur la voie de sortie unique; un moyen pour développer un rapport de la puissance de crête sur la puissance moyenne (161) connecté pour recevoir des entrées à partir du moyen de contrôle d'une puissance de crête et du moyen de contrôle d'une puissance moyenne; 45
- un moyen pour modifier les phases (131 à 134) des signaux des émetteurs radio en réponse au moyen de développement quand le rapport dé passe une valeur spécifiée. 50

2. Procédé d'augmentation d'une capacité de prise en

charge de puissance moyenne de l'amplificateur de puissance unique dans un système d'amplificateur de puissance employant un signal porteur radio composé en une pluralité de voies parallèles comportant chacune un émetteur radio, les voies parallèles étant passées dans une voie unique comportant un amplificateur de puissance unique, CARACTERISE PAR les étapes de:

- contrôle d'un niveau de puissance de crête de la voie unique pris en charge par l'amplificateur de puissance unique et détermination s'il dépasse un seuil de puissance;
- modification d'une phase de l'un du signal porteur radio dans au moins une des voies parallèles si la puissance de crête dépasse le seuil; détermination à nouveau si la puissance de crête dépasse le seuil;
- modification d'une phase du signal porteur radio dans une autre des voies parallèles; et arrêt de la modification des phases des signaux porteurs radio quand la puissance de crête n'atteint pas le seuil.

FIG. 1

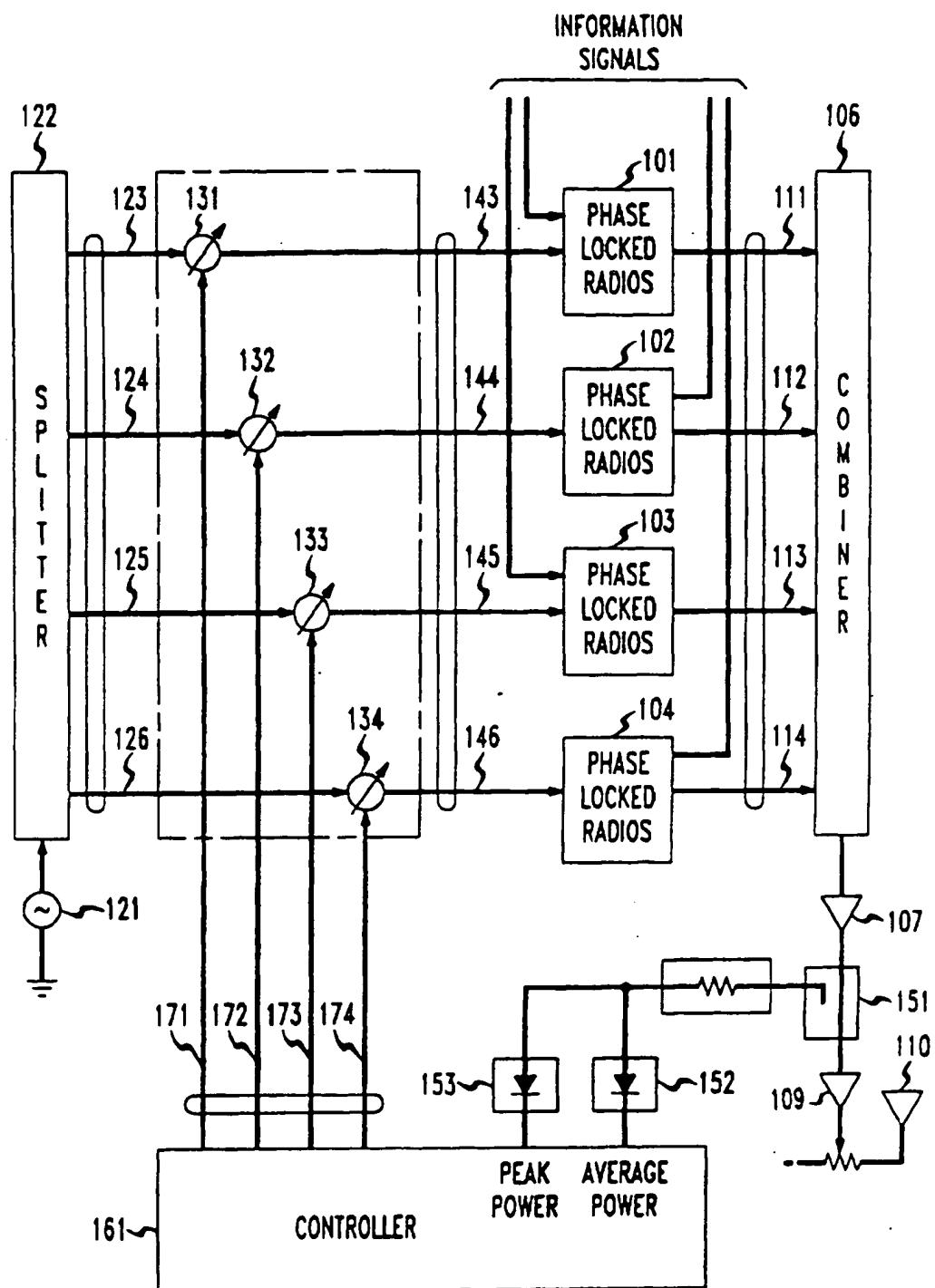


FIG. 2

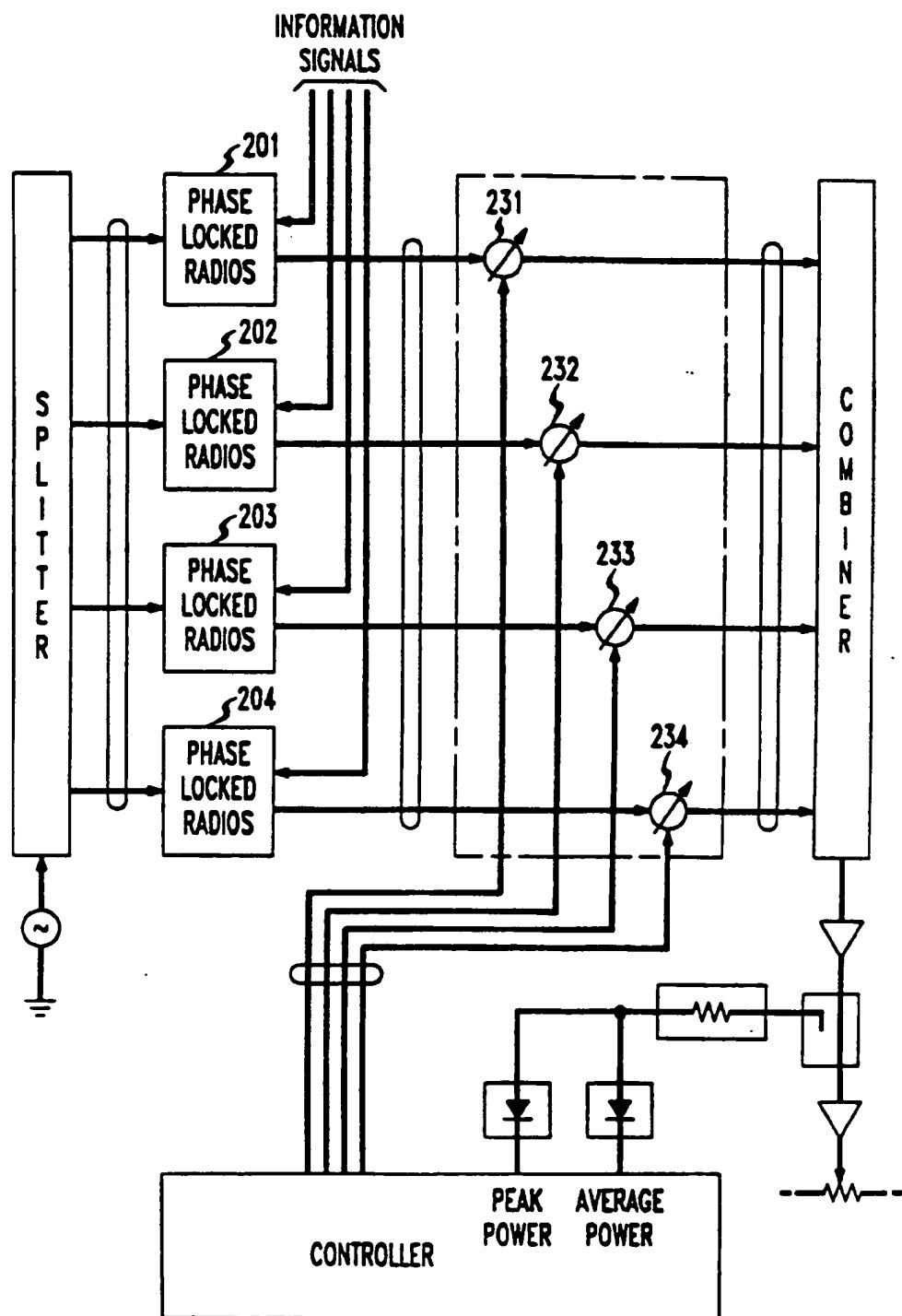


FIG. 3

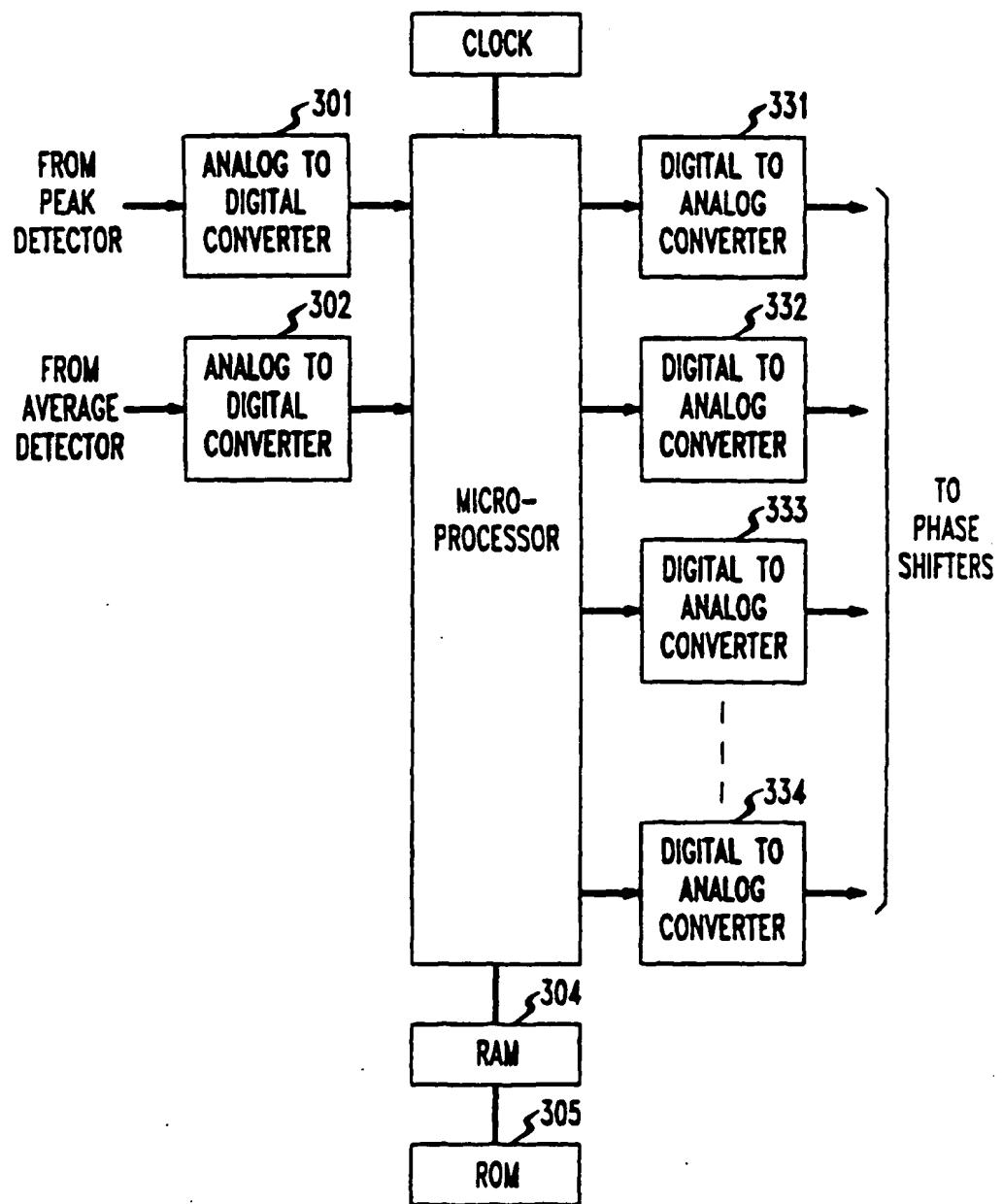


FIG. 4

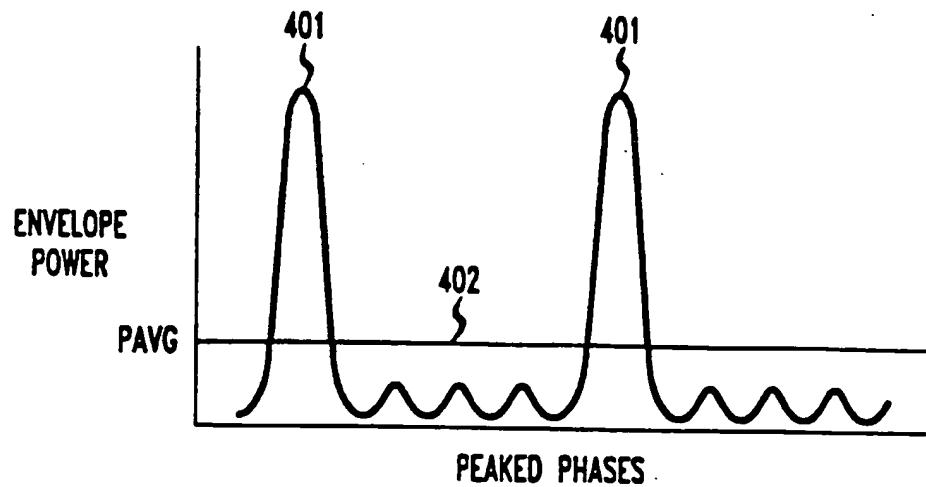


FIG. 5

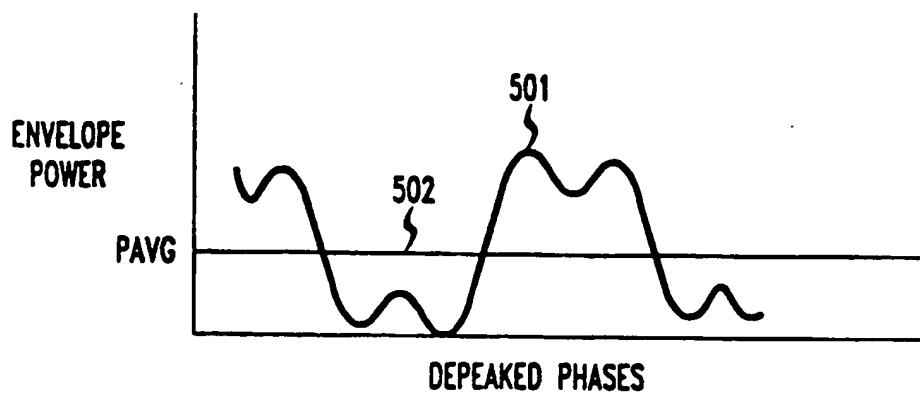


FIG. 6

